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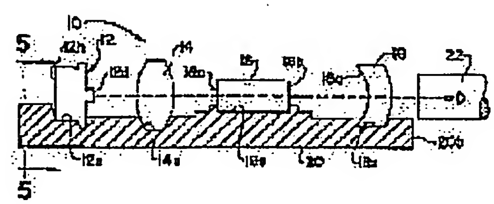
(54) LASER SYSTEM

(57)Abstract:
PURPOSE: To enable pumping of an optical fiber with a minimum dispersion loss caused by an output wavelength, without the use of additional arrangements by providing a laser material for a holder, in such a manner that an angle between at least one optical axis and a transmission axis is between a specific range.
CONSTITUTION: Optical radiation from a pump source 12 is focused on an end 16a of a laser material 16 by a lens 14. Preferably, the laser material 16 is of a solid state and pumped by optical pumping radiation from a laser diode source. The laser material 16 is provided to a holder 20, so that an angle between at least one optical axis and a transmission axis D is between 0 and 90° C, so that the holder when accepting light from the source 12 has an optical spectrum, including a main polarized light dependent spectrum peak at a wavelength nearly equal to the zero-dispersion wavelength of an optical fiber 22. Thereby the laser can pump the optical fiber 22 with a minimum dispersion loss.



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CLAIMS .

[Claim(s)]

[Claim 1] (a) The holder which has the 1st edge which receives the pumping light from a source, and the 2nd edge which counters the 1st edge of the above which transmits a laser beam to an optical fiber, and has the predetermined axis of circulation of a direction which connects between these edges, (b) It is arranged at the above-mentioned holder so that it may be attached between the above-mentioned edges of the above-mentioned holder at the above-mentioned holder, it may have at least one optical axis and the include angle between at least one optical axis of a parenthesis and the above-mentioned axis of circulation may consist of 0 degree for 90 degrees. Laser system equipped with the laser material which has the optical spectrum which includes the main polarization dependence spectrum peak in wavelength almost equal to the zero-dispersion wavelength of the above-mentioned optical fiber when the light from the source of the above is received.

[Claim 2] Laser system of claim 1 whose zero-dispersion wavelength of the above-mentioned optical fiber the above-mentioned material is equipped with Nd:YLF, the above-mentioned include angle is an include angle from about 30 degrees to about 60 degrees, and the wavelength of the light which the source of the above generates is about 1.3 micrometers, and is about 1310nm.

[Claim 3] It is the laser system of claim 2 which the above-mentioned holder is a cylindrical shape, and is the solid-state cylindrical shape which it has the crevice (it has the shaft of the same direction as the above-mentioned axis of circulation) which combines the 1st and 2nd edges of the above, and the above-mentioned laser material is attached in the above-mentioned crevice of the above-mentioned holder, and has two fields which carry out phase opposite.

[Claim 4] The above-mentioned cylindrical shape laser material is the laser system of claim 3 which has a field equipped with a means to approach the 1st edge of the above of the above-mentioned holder, and to make the wavelength near [from the source of the above] the wavelength penetrate optically, and to reflect optically the wavelength near [above-mentioned] the zero-dispersion wavelength by the high ratio.

[Claim 5] Laser system of claim 4 with which the field which counters the above-mentioned field of the above-mentioned material is equipped with a means to approach the 2nd edge of the above-mentioned holder, and to make the wavelength near [above-mentioned] the zero-dispersion wavelength penetrate optically.

[Claim 6] The system of claim 1 whose above-mentioned laser material is the crystal by which rare earth can be doped and a pump can be carried out with a laser diode means.

[Claim 7] The system of claim 6 whose above-mentioned laser material is a neodymium doped lithium yttrium fluoride.

[Claim 8] It is the system of claim 1 cut by equipping the above-mentioned laser material with two crystals of Nd:YLF which adjoins mutually, and cutting one of these so that that optical axis may make the include angle of about 90 degrees to the above-mentioned axis of circulation so that, as for another side, that optical axis may make the include angle of about 0 degree to the above-mentioned axis of circulation.

[Claim 9] The system of claim 1 which is the acute angle whose above-mentioned include angle is not 0 degree.

[Claim 10] The system of claim 1 whose above-mentioned laser material is monopodium birefringence laser material.
[Claim 11] The system of claim 1 characterized by the above-mentioned laser material by the optical ellipsoid which defines the above-mentioned optical axis.
[Claim 12] (a) It has two flanks of the 2nd flank which transmits the 1st flank and laser beam output which are a maintenance means for holding laser material, and receive the pumping luminous radiation from a source which carry out phase opposite. Furthermore, a maintenance means by which the axis of circulation of the light which these two flanks are arranged in parallel mutually, and is transmitted to the 2nd flank from the 1st flank of the above is defined, (b) Characterize by optical ellipsoid and it has polarization dependence gain and an absorption spectrum. Laser system equipped with the doped birefringence laser material which is arranged at the above-mentioned maintenance means at the predetermined include angle between the above-mentioned axis of circulation and at least one shaft of the above-mentioned optical ellipsoid so that it may have one polarization laser output spectrum peak in predetermined wavelength.
[Claim 13] Laser system of claim 12 equipped with the Nd:YLF rod which has the a-axis to which the above-mentioned laser material makes a right angle to the axis of ordinate which is in agreement with the above-mentioned axis of circulation, the c-axis which makes an acute angle to the above-mentioned axis of circulation, and the above-mentioned axis of circulation.
[Claim 14] Laser system of claim 13 put on the location close to the 1st flank of the above of the above-mentioned maintenance means in the above-mentioned maintenance means in order for the above-mentioned rod to have two parallel edges and to transmit light to a fiber optic means of the above-mentioned edge by which come out on the other hand and a certain 1st edge has zero-dispersion wavelength almost equal to the above-mentioned predetermined wavelength.
[Claim 15] Laser system of claim 14 with which the 1st edge of the above of the above-mentioned rod has high reflexibility to 1313nm, and has permeability to about 792nm, and the 1st edge of the above of the above-mentioned rod and the 2nd edge which carries out phase opposite have at least 0.25% of reflexibility to 1313nm.
[Claim 16] Laser system of claim 13 which has an ellipse cylinder crevice to equip the above-mentioned maintenance means with the above-mentioned rod in the middle of the 1st and 2nd flanks of the above of the above-mentioned maintenance means.
[Claim 17] Laser system of claim 12 chosen from the group which the source of the above becomes from a laser diode, a laser diode array, high brightness diode, and a high brightness diode array.
[Claim 18] Laser system of claim 12 which is equipped with two rod-like elements of Nd:YLF with which the above-mentioned laser material has been arranged by approaching mutually, has the axis of circulation one of these turned [axis of circulation] to the direction of an a-axis of the above-mentioned YLF crystal, and has the axis of circulation another side turned [axis of circulation] to the direction of a c-axis of the above-mentioned YLF crystal.
[Claim 19] Laser system of claim 12 which has the axis of ordinate on which the above-mentioned laser material is cut into from Boolean one of Nd:YLF, and makes the include angle of about 45 degrees to the above-mentioned Boolean c-axis.
[Claim 20] (a) The laser material by which a pump is carried out in the source which has at least one optical axis and the absorption spectrum which includes predetermined wavelength and the spectrum peak in polarization in a polarization dependence gain list, and is characterized with pumping wavelength, (b) The above-mentioned spectrum peak has a certain predetermined

property, when propagation meets a certain crystallographic axis. And a means to form the laser cavity which is made to carry out laser oscillation of the above-mentioned material which has other predetermined properties, and supplies laser to an optical fiber along the above-mentioned propagation when the above-mentioned propagation meets other crystallographics axis, (c) by arranging the above-mentioned laser material along the above-mentioned propagation of the predetermined acute angle which is not 0 degree which is among the above-mentioned cavity and is an include angle between the two above-mentioned crystallographics axis the above-mentioned spectrum peak -- the account of a top -- the laser system for supplying an optical fiber equipped with a means to suit the zero-dispersion wavelength of the preselected optical fiber in the above-mentioned absorption spectrum so that it may be located between a certain predetermined property, and a predetermined property besides the above.

[Claim 21] The above-mentioned laser material is the laser system of claim 20 equipped with Nd:YLF cut from Boolean one of Nd:YLF so that the above-mentioned axis of circulation might serve as an acute angle it is not [acute angle] 0 degree to the c-axis of YLF.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] Especially this invention relates to laser system with desirable light being supplied on specific wavelength, i.e., being used about general laser.

[0002]

[Description of the Prior Art] In laser system, what (it uses) the light of specific wavelength is supplied for may be desirable. By controlling the wavelength of a laser beam, operation mode (for example, Q switch) can be optimized, and the optical noise under output can be decreased (for example, contention mode). Furthermore, as for a laser output, in the system to which a laser beam is made to transmit the inside of an optical fiber, it is desirable that it is the point of the optical fiber in zero-dispersion wavelength, i.e., a system.

[0003] It is shown that diode pump neodymium laser is very useful as a source of high power laser of fiber optic SUBIDEO and microwave transmission. As for this laser, it is common to be used as a stable source of a continuous wave (CW) of external modulation equipment like a lithium niobate waveguide mold modulator. Thus, when used, it is important that there is no outpatient department noise induced by the above-mentioned laser. Movable [of the above-mentioned laser] is carried out by the single transmission mode, and it removes the beat of other transmission modes. Similarly, the above-mentioned laser must polarize in order to avoid the beat between frequency shift orthogonal modes. An external modulator is important for polarization control also from the reason for being sometimes sensitive to polarization. Moreover, it is necessary to remove the mode beat between the contiguity longitudinal modes. This is attained by shortening the die length of a laser cavity. For example, the bandwidth of 30GHz can realize the optical path length of a cavity by shortening only 1cm or less both ways. However, when a structure like a BURYU star plate polarizer (structure which is easy to lengthen cavernous length considerably) is used especially, implementation is difficult for such cavities. In the case of an one-(monolith target) laser cavity, it is easiest to make laser cavernous length shortest-ize.

[0004] If laser system works normally, the bandwidth of fiber optic SUSHISUTEMU will be determined by the distributed property of a fiber. The propagation velocity of the light pulse in

the inside of a fiber is determined by the group velocity v defined by v=c [d (n/lambda)/d (1/lambda)]. Here, c is the rate of light and n is the actual value of the refractive index of a fiber. Since it is dependent on the configuration of a fiber, the actual value of n is not correctly in agreement with the value of a bulk dissolution silicon dioxide (bulk fused silica) with the waveguide effectiveness. As for the wavelength dependency of v, being expressed by the distribution D defined by D=dv/dlambda is common. Distribution of a dissolution silicon dioxide is S0 here, although it is common to be expressed by empirical formula like D(lambda) = (S0 / 4) [lambda- (lambda04/lambda3)]. And lambda 0 A value is given by the fiber manufacturer. Lambda=lambda 0 It solves, and although D (lambda) serves as zero, this is "zero-dispersion wavelength" of a fiber, and it is for 1300nm and 1320nm typically.
[0005] In many cases, the light pulse which carries information through a fiber has width-of-face [not monochrome but] **lambda. As for this width of face, defining as half-value width (FWHM) is common, and, as for wavelength actual also about the source of multiplex longitudinal-mode laser, consisting of some discontinuous peaks is common. The wavelength component from which the pulse differed for distribution is spread at a different rate. It leads to taking this for a pulse progressing the inside of a fiber, and pulse width extending it. Consequently, distortion of a lightwave signal decreases a signal modulation factor, without decreasing all power. Although this distortion is characterized by breadth **t of the pulse defined by **t=D (lambda) [** lambda/L], L is the die length of an optical fiber here. The above-mentioned formula expresses the difference of the propagation time of the pulse which is two whose wavelength is lambda- (**lambda/2) and lambda+ (**lambda/2). Lambda=lambda 0 It solves, and it is set to D(lambda) = 0 and **t=0 (namely, when laser carries out the pump of the optical fiber with zero-dispersion wavelength).
[0006] The information bandwidth of a fiber is first determined by the breadth of a pulse. If amplitude modulation of the light source which has equal two peak wavelength lambda- (**lambda/2) and lambda+ (**lambda/2) is carried out to the sine wave of f= 1/of frequencies (2**tau), the modulation factor of an output will become zero. The output of this of lambda- (**lambda/2) is because a phase is shifted only for the half-wave length about the output of lambda+ (**lambda/2). Although thought here by the pulse which has only two factors, if a more [in spectrum] uniform pulse is used, the loss of a modulation is not this much dramatic. Generally as the result, f= 1/(2**tau) of frequencies is described like the "3-dB light bandwidth" of a fiber. The propagation bandwidth of a fiber can be made to maximize by minimizing D (lambda) or **lambda. Preferably, the source of laser is chosen so that it may work on the wavelength possible nearest to the wavelength from which laser becomes the zero-dispersion wavelength (for example, 1301.5 to 1321.5 nm) of an optical fiber, D(lambda 0) = 0 [i.e.,], and an optical fiber may be supplied.
[0007] The other problems which arise in application of fiber OPUTIKUSU are stimulated Brillouin scattering (SBR) [J.Opt.Soc.Am.B. by AOKI (Aoki) etc., 5 (2), and 358 - 363 pages] (1988). SBR is a nonlinear loss device, and when the source of high power laser is long and is made to spread the inside of the optical fiber of low loss, it becomes important. As for the spectrum output of diode pump neodymium laser, it is common to consist of some modes in which it has the line breadth of the kilohertz unit in which spacing of several GHz opened. As shown by AOKI etc., when the power per mode exceeds a certain threshold, on these conditions, SBR poses a problem. Therefore, since power is distributed to each mode, the maximum-permissible power in the inside of a fiber is determined by the number of the oscillation modes of pump LD. Since it is attained by using the large laser material of a gain peak, although big

frequency spacing is required for the laser which fills such demands, it can work some longitudinal modes. Of course, the laser oscillation spectrum of laser may be narrower than the width of face of a gain peak. The effectiveness in the laser to which it is easy to carry out multiplex longitudinal-mode operation (for example, spatial hole burning) of the laser must be carefully optimized, if the line breadth at the time of actuation is made to make it max.

[0008] The optimal condition of the spectrum of laser is determined by at least three factors in application of fiber OPUTIKUSU in a GIGAHERUTSU field. From a mode beat noise, it is required that mode spacing should be large as much as possible. Since conditions required in order to control SBR suggest use of laser material with wide gain peak width, the longitudinal mode which was able to open some large spacing can be worked. Demand that a fiber transmission bandwidth is large leads the conditions of making D(lambda) **lambda into min to the last. This condition is satisfied only when laser is worked on the wavelength from which D (lambda) serves as zero when the value of **lambda is large. Thus, the polarization laser which has a short laser cavity which is the longitudinal mode which was able to open some large spacing, and works on the zero distribution point of a fiber is needed.

[0009] Diode pump neodymium laser is a useful source of high power for fiber optic SUBIDEO transmission. Especially one useful source of a laser beam is a laser diode pump-neodymium dope yttrium RICHIUMUFUTSU ghost (Nd:YLF, i.e., NYLF). 1047nm and strong 1-micrometer transition by 1053nm are widely used for a Q switch, mode locking, and application like the formation (intracavity doubling) of a twice as many internal cavity as this. Although 1321nm and weak 1.3-micrometer transition by 1313nm are also interesting, especially 1313nm line is zero-dispersion wavelength lambdao in a silicon-dioxide fiber. It is interesting in respect of application of fiber OPUTIKUSU at the reason for being very near.

[0010] A birefringence laser crystal like Nd:YLF is characterized by optical ellipsoid, and it has typically the strong gain and the strong absorption spectrum of a polarization dependency. In Nd:YLF, strongest 1-micrometer (4 F3/2 -> 4F11) transition is 1047nm [sigma(pi) =18x10-20 cm2] and 1053nm [sigma(sigma) =12x10-20 cm2]. 1.3-micrometer (4 F3/2 ->4 I13/2) transition equivalent to these is 1313nm [sigma(sigma) =3x10-20 cm2] and 1321nm [sigma(pi) =3x10-20 cm2]. Furthermore, 800nm absorption spectrum polarizes strongly. In Nd:YLF, an absorption spectrum consists of the two main peaks, 792nm and 797nm, 1%, 792nm is alpha(sigma) =1cm-1 and alpha(pi) =9cm-1, and 797nm of these absorption coefficients is alpha(sigma) =3cm-1 and alpha(pi) =6cm-1. The pump of Nd:YLF will be simply carried out by about 800nm laser diode synchrotron orbital radiation by this.

[0011] The host crystal of yttrium aluminum perofskite (YAlO3, i.e., YAP, or YALO) is used for other laser. The polarization dependence gain of YALO is reported. Alternative loss of polarization all over a cavity (For example) Polarization like BURYU star prism, and a wavelength selector Appl.Phys.Lett. by [MASEI (G. A.Massey) by which the laser oscillation property by the pumping in alignment with the crystal main shaft accompanying the increment by using is investigated, the 18th volume, No.1 (1971), Jour.Quantum by MASEI Electron., QE-8 volume, No.7 (1972), 669 - 674 pages, and Optics by abb RAMOBITCHI (A. Abramovici) Comm, the 61st volume, No.6 (1987), 401 -404-page]. The polarization and wavelength selection nature of a laser cavity which used YALO about various fluorescence spectra are reported to Appl.Phys.Letts by a weber (M. J.Weber) etc., the 15th volume, No.10 (1969), and 342 - 345 pages. It is suggested to Appl.Phys. by the weber, the 42nd volume, No.42 (1972), and 4996 - 5005 pages that the anisotropy of the stimulated-emission cross section of the main shaft about various transition of the Nd dope YAP can suit specific laser application in Nd:YAP.

Appl.Phys.Letts. by a bus (M. Bass) etc., the 17th volume, No.9 (1970), and especially 395-398 pages inquire about Q switch actuation in which Nd dope YALO laser was improved, and the gain factor of Nd in YALO being dependent on the crystal orientation nature of a laser rod main shaft and selection of the crystallographic axis of the optimal gain characteristics are further reported to them. However, the same research result about YLF is not obtained yet.

[0012] As for Nd:YLF laser, it is common that the include angle theta between an optical axis (namely, crystal c-axis) and an axis of circulation is worked at 90 degrees, a pumping is performed for propagation by 792nm pi polarization absorption peak along with an a-axis, and laser oscillation is performed by 1047nm transition of pi polarization. If a 1-micrometer cavernous reflector is used, 1047nm radiation of pi polarization of the power between 50-100mW will be obtained. Typically, the linearity polarization of this output is carried out by 1000:1 or more polarization ratios. Positive single line operation (1047nm or 1053nm) is attained by arranging a BURYU star plate on pi of a crystal, or sigma shaft. Equivalent power is obtained also in which wavelength. However, output polarization is very sensitive to the array of the shaft of a BURYU star plate, and a crystallographic axis. As shown by the Jones matrix analysis, ** to which a little arrays come makes a polarization output an oblong. Furthermore, it not only increases the magnitude (die length) of the whole source of laser, but a BURYU star plate decreases effective power.

[0013] 1053nm laser oscillation whose sigma polarization Nd:YLF did has two problems, although it is realizable at theta= 0 degree (namely, propagation in alignment with a c-axis). The first problem is that laser already polarizes and there is (that is, operation by both polarization is possible) first. [no] For a mechanical reason, the birefringence of few include angles from which it divides laser into two groups (it is easy to carry out laser oscillation of both) of two or more orthogonal modes since it is not guaranteed any longer that propagation meets a c-axis correctly arises. When laser spreads along with a c-axis, to an optical axis, rather than laser power with an include angle of 90 degrees (theta= 90 degrees), typically, I hear that the 2nd problem has low output power, and it has it no less than 20%. At theta= 0 degree, only comparatively weak sigma polarization spectrum depends this on the inefficient nature of the pumping that a pump is possible. Moreover, control of laser light polarization is also difficult in this case. Although one of the polarization can be stopped by adding a BURYU star plate to a cavity, step must be correctly kept with a crystallographic axis with difficult discovery, otherwise, it becomes a RIOTTO filter (see the supra by umbra MOBITCHI (Ambramovici) about Nd:YAP). Generally, it is easy to add a BURYU star plate to the rod of the easy a-axis of discovery.

[0014] Similarly, the Nd:YLF laser system which polarized can work by 1313 and 1321nm. Generally, the output of 25-50mW is obtained with the input control power of 200mW. If Nd:YLF laser is worked on the conditions of BURYU star plate nothing and theta= 90 degrees, laser will work to coincidence by both 1313nm line of sigma polarization, and 1321nm line of pi polarization. These two lines have the same gain substantially, and it tends to carry out both laser oscillation.

[0015] Operation by the two above-mentioned lines is seen by many laser material in 1.3 micrometers. For example, it is Nd:GGG which works by 1323 and 1331nm in Nd:YAG which works by 1319 and 1338nm, and a list. In many **, only when the RIOTTO filter or an additional wavelength selection element like an etalon is added to the laser cavity, single line operation is made. In Nd:YLF, polarization control with a BURYU star plate is used in order to realize single line operation on one of wavelength. Although 1313nm operation is made by the

propagation in alignment with a c-axis (namely, theta= 90 degrees), it has the same pumping as the 1053nm laser in alignment with a c-axis, and the problem of polarization.
[0016]
[Problem(s) to be Solved by the Invention] U.S. Pat. No. 3,624,545 (No. 1971 November 30 issue) by the loss (Ross) is described about the optical pump solid state laser which consists of the YAG rod by which a flank pump is carried out by at least one semi-conductor diode laser. Similarly, in order that U.S. Pat. No. 3,753,145 (August 14, 1973 issue) by Choi Sulla (Chesler) may carry out the edge pump of the neodymium dope YAG rod, it is said that one or more luminescence semiconductor diodes are used. Using the array of a pulse diode laser, in order to carry out the edge pump of solid-state-laser material like the neodymium dope YAG is stated to U.S. Pat. No. 3,982,201 (No. 1976 September 21 issue) by Rosencrantz (Rosenkranttz) etc. Appl.Phys.Lett. according to Sipes (D. L.Sipes) to the last, the 47th volume, and No. -- in order to carry out the edge pump of the neodymium dope YAG, by using the semi-conductor diode laser array which focused strongly reported 2, 1985, and 74 - 75 pages of things for which the pumping radiation which has the wavelength of 810nm is changed into the output radiation which has the wavelength of 1064nm at high effectiveness.
[0017] Although a certain kind of the polarization dependence gain and the absorption spectrum of a birefringence laser crystal are recognized in the above-mentioned reference, as for such a crystal, it is common to be worked at theta= 0 degree or theta= 90 degrees. A more important thing is zero-dispersion wavelength lambda 0. It is not combined with the directivity of a laser crystal [how it can use for fitting that the effectiveness acquired by working an optical fiber optimizes the shaft of propagation, and directivity optimizes the performance in laser operation mode, decreasing an optical noise, or an optical spectrum].
[0018] One of the purposes of this invention is offering the new laser system which carries out the pump of the optical fiber so that laser's may make distributed loss min.
[0019] It is compact and other purposes of this invention are things which used without the additional optical element for the optical fiber Nd:YLF which supplies polarization and for which laser system with sufficient energy efficiency is offered.
[0020] The further purpose of this invention is offering laser system equipped with birefringence laser material and the holder which arranges this laser material so that the pumping in zero-dispersion wavelength may be made.
[0021] The further purpose of this invention is offering the diode pump Nd:YLF laser of an easy configuration of consisting of the fewest possible structures which carries out the pump of the optical fiber by about 1.3 micrometers.
[0022] this invention -- being the further -- others -- the purpose is offering the means to which the output spectrum of laser system is fitted.
[0023]
[Means for Solving the Problem] In order to attain the above purpose, the laser system of this invention The holder which has the edge which receives the pumping light from a source, and the opposite edge which transmits a laser beam to an optical fiber, and has the predetermined axis of circulation of a direction which connects between these edges, It is arranged at the above-mentioned holder so that it may be attached between the edges of the above-mentioned holder at the above-mentioned holder, it may have at least one optical axis and the include angle between at least one optical axis of a parenthesis and the above-mentioned axis of circulation may consist of 0 degree for 90 degrees. When the light from the source of the above is received, it has the laser material which has an optical spectrum including the main polarization dependence

spectrum peak in wavelength almost equal to the zero-dispersion wavelength of the above-mentioned optical fiber.

[0024] Since birefringence solid-state-laser material like Nd:YALO or Nd:YLF has the gain factor of transition of a strong polarization dependence absorption spectrum and dope material typically, control in the operation mode of laser equipped with such a gain medium is made by control of the direction of the crystallographic axis of the laser material in polarization or a laser cavity. In birefringence solid-state-laser material, a gain factor is dependent on the include angle theta and crystall luminescence shaft over the optical path which passes along a crystal. Furthermore, it is expressed by the refractive index of that this relation is normal and the crystal to abnormality polarization, and the trigonometric function of an include angle theta although the parameter relation showing a gain factor which is different on the various transition lines of the dope material under crystal exists [Born (M. Born) and Principles of Optics by WORUFU (E. Wolf), the 6th edition, Chapter 14, Pergamon Press, New York 1980]. So, a gain factor is optimized by choosing theta.

[0025] One important application of this invention is fitting output wavelength to the zero-dispersion wavelength of the optical fiber combined with the output of laser. According to this invention, an output polarizes without [without it uses a BURYUTA plate, and] changing the energy of other wavelength, the output wavelength of laser is united with the zero-dispersion wavelength of an optical fiber, and a frequency beat also decreases. Furthermore, since a conventional polarization control means like a BURYU star plate is unnecessary, the die length and magnitude of the whole laser can be decreased.

[0026] Many of other advantages and descriptions of this invention are described in the following examples.

[0027]

[Example] Although this invention can be carried out with many gestalten, two examples are describing below. It does not pass over these to what shows an example of this invention, and this invention is not restricted to these.

[0028] Each structure of the elementary solid-state laser system 10 is illustrated by drawing 4 . Especially, in this example, it has the source 12 of a pump, a lens 14, the laser material 16, the output coupler 18, and the holder 20 as a source, a lens, laser material, and an output coupler. A holder 20 has edge 20b transmitted to an optical fiber 22 in light from laser material along with an axis of circulation D.

[0029] An optical pumping means, i.e., the optical radiation from a source 12, focuses to edge 16a of the laser material 16 with the focus means 14, i.e., a lens, in more detail. Preferably, the laser material 16 is solid ** and is ** in which a pump can be carried out by the optical-pumping radiation from the source of a laser diode. The light emitted by the laser oscillation of the laser material 16 is contained all over the linearity stationary wave optical cavity defined by reflective covering of the front face of reflecting surface 18a of the output coupler 18, i.e., a mirror, and opposite edge 16a of laser material. The laser material 16 is manufactured by cutting so that I may hear that the optical path which passes along a crystal has a certain relation to a crystall luminescence shaft and it may be defined, so that it may be explained in detail later.

[0030] The holder has composition which supports the main structures of laser system 10 about the holder 20, i.e., a maintenance means. As illustrated especially, the holder 20 has two or more crevices for attaching other structures of laser system 10, and Slot 12s, 14s, 16s, and 18s, i.e., scooping outs. If the above-mentioned structure is attached in these slots, these structures will be automatically arranged in the direction of an optical axis D, i.e., the shaft of propagation. These

structures are fixed to a holder 20 by using the conventional mechanical means or the conventional conventional adhesion means (namely, bond material) like screw attachment. The more detailed contents about a holder are described at United States patent 4th transferred to the applicant of this invention, and No. 31,795. This contractor will admit that it is not necessary to equip a holder 20 with a lens 14, and that the output coupler 18 is attached in end 16b of the laser material 16 from the following explanation.

[0031] Preferably, although the laser material 16 contains the solid-state chosen from the group which an active substance and an active substance become from the vitrification and the crystallization base material which are having the matter which is the stoichiometric component of laser material doped, it is not restricted to this. More preferably, although an active substance contains the ion of chromium, titanium, and a rare earth metal, it is not restricted to this. It is describing in more detail about the conventional solid-state-laser material CRC Handbook of Laser Scienceand Technology, the 1st volume, the Weber (M. J.Weber) work, CRC company issue, 1982, 72 - 135 pages and Laser Crystals by Kaminsky, the 14th volume of the SHUPU ringer series of optics, a SHUPU ringer company, and 1982. The conventional base material to neodymium ion contains a glass yttrium aluminum garnet (Y3 A15O12, i.e., YAG), YAlO3 (it is described as YALO or YAP), the neodymium dope LiYF4 (it is described as YLF), Gd3 Ga 5O12 (it is described as GGG), and Gd3 Sc2 Ga 3O12 (it is described as GSGG). When used as an example as laser material of the solid-state laser system with which the pump of the neodymium dope YAG is carried out optically, by absorbing the light which has the wavelength of about 808nm, the pump of this laser material can be carried out, and it can emit the light which has the wavelength which is about 1064nm or about 1320nm.

[0032] A source 12 is equipped with the heat sink and/or 12h of thermoelectric-cooling equipment relevant to laser diode 12d and this by the example shown in drawing. Using a flash lamp, light emitting diode (here, high brightness diode and a high brightness diode array being included), and a laser diode (here, a laser diode array being included) for the pump of solid-state-laser material, i.e., excitation, is known well. Conventional light emitting diode and a conventional laser diode carry out output radiation which has the wavelength of the range of about 630 to about 1600nm as a function of a constituent. Such equipment that carries out pump radiation of wavelength effective for carrying out the pump of the laser material 16 is used for practical use of this invention. For example, the wavelength of the equipment based on GaAlAs is changed to about 750 to about 900nm by changing the constituent of equipment. The source based on GaAlP emits the wavelength of the range from about 1000nm to about 1600nm by the same approach. A suitable power source is used at the time of operation of an optical-pumping means. The electric code from the source 12 of laser to a power source is not shown all over drawing.

[0033] That of a lens 14 is that ****** makes the light from a source 12 focus to the laser material 16. All the conventional means for a focus can be used. For example, the combination of a refractive-index change lens (GRIN), a ball lens, an aspheric lens, or an optical element etc. is used. If laser diode 12d is used as a source 12 of a pumping, the edge on the front face of an output of a laser diode, i.e., a source, will be put on field 16a on the front face 16 of an input, i.e., laser material, and the relation (butt-coupled relationship) of base association, without using a lens 14. Base association means association near enough to which only 1 mode volume carries out the pump of the laser material 16 with a transmission interruption area small enough here, in order that the emission beam of the pumping radiation emitted from the source of a laser diode may essentially support only one transmission-mode laser operation (namely, TEM00) in laser

material.
[0034] The light emitted by the laser material 16 is turned to an optical fiber 22 by the output coupler 18. The optical coupler 18 is like the mirror which penetrates some of light (they are not all) emitted from the laser material 16. For example, internal-surface 18a may be equipped with covering used for this coupler from the former which has about 95% of reflection factor. Covering of the same class as this is applied to opposite edge 16b of the laser material 16. In such a case, the main function can transpose the output coupler 18 to the optical means which is making parallel light given to an optical fiber 22.
[0035] An optical fiber 22 is the conventional thing. As an example of the optical fiber of the communication link type of Corning, Inc. [Corning glass (Corning Glass Works), the Corning communication link section, New York, 14831, and the U.S.] which can be got in a commercial scene, it is SMF-28 at the zero-dispersion wavelength of 1314nm and 1312nm, respectively. CPC3 Single-mode optical fiber and SMF-21 CPC3 There is single-mode optical fiber.
[0036] Since the laser material 16 is cut from Boolean (boule: rough, for example, Nd:YLF) one of a crystal unlike the conventional thing, the crystallographic axis (c-axis) has the acute angle theta to Propagation D (refer to drawing 1). The laser material 16 is carrying out the exact cylinder, i.e., a rod configuration, here. However, all the configurations known from the former are used. The laser material 16 is equipped with the Nd:YLF rod whose concentration of Nd is about 1 atom % by a certain example. Edge 16a is covered so that 85% or more may be made to penetrate in the wavelength (for example, 792nm) of the light from a source 12, and so that it may have a high reflection factor (HR) in output wavelength (for example, 1313nm) almost equal to the zero-dispersion wavelength of an optical fiber 22. Opposed face 16b is covered so that it may have 0.25% or less of reflection factor in output wavelength. As a certain example, the laser material 16 is 5mm in the diameter of 3mm, and die length.
[0037] About the theta= 45-degree axis of circulation D, the 1313nm gain in an ordinary ray becomes larger than the gain of one of the lines in an extraordinary ray to a c-axis, and polarization single line laser oscillation is possible. This is realized also at an include angle like the throat between about 30 to 60 degrees (at such an include angle, the gain of an extraordinary ray decreases 25% from peak value). Making it work near theta= 60 degree by the reason for emphasizing the strong pi polarization component of an absorption spectrum has many advantages. "Walk-off" (namely, birefringence) is equipped with additional polarization and a wavelength selection device. Normal and extraordinary-ray mode separate from input edge 16a of the YLF crystal 16 spatially mutually. For this reason, one of the modes can be efficiently laid on top of a pump spot. If the greatest superposition is carried out about a normal mode, the wavelength selection effectiveness will tend to be reinforced by this.
[0038] All over the cavity as shown in example drawing 4 , the theta= 45-degree laser using the 4mm length Nd:YLF laser rod whose Nd concentration is about 1% was made. The curved-surface reflector 18 with which radius of curvature reflects 1.32 micrometers 99.5% by 70mm was used in order to form a cavity with a die length of 26mm. The laser power exceeding 25mW was simply obtained by 792 or the 797nm pumping. The linearity polarization of the output beam was carried out by 1000:1 or more polarization ratios. It turned out that the spectrum of an output beam is measured by the 0.35m monochromator, consequently it consists of some longitudinal modes centering on 1313nm. Vibration was not detected in any of other wavelength between 1310 and 1400nm. Although the transmission-mode profile of a laser output was in agreement with the GAUSHAN profile, this shows that single transmission-mode operation was attained. This was confirmed by the noise measurement which uses a spectrum analyzer. The

peak divided into the noise spectrum only 5.34GHz which is the description of the mode beat of TEM00 transmission mode was seen. This spacing is determined by cavernous length and this contractor will recognize that it can be made to increase by using a shorter cavity. Furthermore, we used the technique same about Nd:YAG, in order to carry out operation to which the shot noise was restricted by 10MHz to 20GHz.

[0039] Other examples are shown in drawing 6 . Here, laser material consists of two Nd:YLF crystals 16A and 16B which approached mutually. Crystal 16B is cut so that the c optical axis may become about 90 degrees to an axis of circulation. Crystal 16A is cut so that the c-axis may become about 0 degree to an axis of circulation. As for surface 16b close to the front face and the output coupler 18 between these two crystals, it is desirable to be covered so that it may have non-reflexibility (AR) to the wavelength (for example, 792nm of a laser diode) of 1313nm and the source of the above. An output beam will be equipped with about 1313nm sigma polarization if the above arrangement is carried out.

[0040] Although the concept of changing the direction of the crystallographic axis of laser material to an axis of circulation has said that an optical fiber is supplied, larger application is possible for this concept. Since mode competition and mode fluctuation may be minimized in the desired mode, the polarization dependence gain and the absorption spectrum of a birefringence solid-state-laser crystal radical can be used in order to optimize the mode (for example, CW, a Q switch) of laser operation.

[0041] Since a noise is a function near [where laser works] the wavelength, this concept can be used also in order to reduce an optical noise. Furthermore, this concept is applicable to both monopodial and an optically biaxial birefringence laser crystal. Finally, the concept of this invention is applicable to a place, for example, a single wavelength output, i.e., single line operation, where it is required from a laser crystal, specific wavelength, i.e., dominant wavelength, anywhere. It can **, if it avoids attaching other equipments (for example, BURYU star plate etc.) in order that making it equal substantially may have practical availability in the zero-dispersion wavelength of the optical fiber especially related in this wavelength and it may fit an output spectrum to it further.

[0042] Probably, by the above description, various modification will be possible to this contractor. The above description is only for explaining drawing and is aimed at teaching this contractor the method of performing this invention. Much modification is possible to this invention. For example, a holder may be hollowed and can also have the cross section (refer to drawing 5) of a semicircle, a circle, or a rectangle (U.S. Pat. No. 4,731,795 drawing 2). Furthermore, reflecting surface 18a is good also as covering of a up to [edge 16b of the laser material 16]. Moreover, the description of this invention is demonstrated also for much modification and substitution of laser material. For example, 1053nm laser of polarization is realizable using Nd:YLF worked at theta= 30 degrees. Although, as for a normal beam of light, all serve as 1053nm peak of normal polarization, as for an extraordinary ray, 1047nm peak becomes [1053nm peak] 25% 75%. Since 1047nm peak is 1.5 times as large as 1053nm peak, two peaks in an extraordinary-ray spectrum have both smaller than a normal 1053nm peak. Thus, 1053nm operation of polarization has a result. The strongest pump band happens to the abnormality polarization by 797nm. Thus, many design changes are made based on the pneuma of this invention shown in the claim. of course, such modification -- a claim -- it comes out inside.

[0043]

[Effect of the Invention] The laser system which can carry out the pump of the optical fiber so

that the distributed loss by output wavelength may serve as min can be offered without using an additional structure.

TECHNICAL FIELD

[Industrial Application] Especially this invention relates to laser system with desirable light being supplied on specific wavelength, i.e., being used about general laser.

PRIOR ART

[Description of the Prior Art] In laser system, what (it uses) the light of specific wavelength is supplied for may be desirable. By controlling the wavelength of a laser beam, operation mode (for example, Q switch) can be optimized, and the optical noise under output can be decreased (for example, contention mode). Furthermore, as for a laser output, in the system to which a laser beam is made to transmit the inside of an optical fiber, it is desirable that it is the point of the optical fiber in zero-dispersion wavelength, i.e., a system.

[0003] It is shown that diode pump neodymium laser is very useful as a source of high power laser of fiber optic SUBIDEO and microwave transmission. As for this laser, it is common to be used as a stable source of a continuous wave (CW) of external modulation equipment like a lithium niobate waveguide mold modulator. Thus, when used, it is important that there is no outpatient department noise induced by the above-mentioned laser. Movable [of the above-mentioned laser] is carried out by the single transmission mode, and it removes the beat of other transmission modes. Similarly, the above-mentioned laser must polarize in order to avoid the beat between frequency shift orthogonal modes. An external modulator is important for polarization control also from the reason for being sometimes sensitive to polarization. Moreover, it is necessary to remove the mode beat between the contiguity longitudinal modes. This is attained by shortening the die length of a laser cavity. For example, the bandwidth of 30GHz can realize the optical path length of a cavity by shortening only 1cm or less both ways. However, when a structure like a BURYU star plate polarizer (structure which is easy to lengthen cavernous length considerably) is used especially, implementation is difficult for such cavities. In the case of an one-(monolith target) laser cavity, it is easiest to make laser cavernous length shortest-ize.

[0004] If laser system works normally, the bandwidth of fiber optic SUSHISUTEMU will be determined by the distributed property of a fiber. The propagation velocity of the light pulse in the inside of a fiber is determined by the group velocity v defined by v=c [d (n/lambda)/d (1/lambda)]. Here, c is the rate of light and n is the actual value of the refractive index of a fiber. Since it is dependent on the configuration of a fiber, the actual value of n is not correctly in agreement with the value of a bulk dissolution silicon dioxide (bulk fused silica) with the waveguide effectiveness. As for the wavelength dependency of v, being expressed by the distribution D defined by D=dv/dlambda is common. Distribution of a dissolution silicon dioxide is S0 here, although it is common to be expressed by empirical formula like D(lambda) = (S0 / 4) [lambda- (lambda04/lambda3)]. And lambda 0 A value is given by the fiber manufacturer.

Lambda=lambda 0 It solves, and although D (lambda) serves as zero, this is "zero-dispersion wavelength" of a fiber, and it is for 1300nm and 1320nm typically.

[0005] In many cases, the light pulse which carries information through a fiber has width-of-face [not monochrome but] **lambda. As for this width of face, defining as half-value width (FWHM) is common, and, as for wavelength actual also about the source of multiplex longitudinal-mode laser, consisting of some discontinuous peaks is common. The wavelength component from which the pulse differed for distribution is spread at a different rate. It leads to taking this for a pulse progressing the inside of a fiber, and pulse width extending it. Consequently, distortion of a lightwave signal decreases a signal modulation factor, without decreasing all power. Although this distortion is characterized by breadth **t of the pulse defined by **t=D (lambda) [** lambda/L], L is the die length of an optical fiber here. The above-mentioned formula expresses the difference of the propagation time of the pulse which is two whose wavelength is lambda- (**lambda/2) and lambda+ (**lambda/2). Lambda=lambda 0 It solves, and it is set to D(lambda) = 0 and **t=0 (namely, when laser carries out the pump of the optical fiber with zero-dispersion wavelength).

[0006] The information bandwidth of a fiber is first determined by the breadth of a pulse. If amplitude modulation of the light source which has equal two peak wavelength lambda- (**lambda/2) and lambda+ (**lambda/2) is carried out to the sine wave of f= 1/of frequencies (2**tau), the modulation factor of an output will become zero. The output of this of lambda- (**lambda/2) is because a phase is shifted only for the half-wave length about the output of lambda+ (**lambda/2). Although thought here by the pulse which has only two factors, if a more [in spectrum] uniform pulse is used, the loss of a modulation is not this much dramatic. Generally as the result, f= 1/(2**tau) of frequencies is described like the "3-dB light bandwidth" of a fiber. The propagation bandwidth of a fiber can be made to maximize by minimizing D (lambda) or **lambda. Preferably, the source of laser is chosen so that it may work on the wavelength possible nearest to the wavelength from which laser becomes the zero-dispersion wavelength (for example, 1301.5 to 1321.5 nm) of an optical fiber, D(lambda 0) = 0 [i.e.,], and an optical fiber may be supplied.

[0007] The other problems which arise in application of fiber OPUTIKUSU are stimulated Brillouin scattering (SBR) [J.Opt.Soc.Am.B. by AOKI (Aoki) etc., 5 (2), and 358 - 363 pages] (1988). SBR is a nonlinear loss device, and when the source of high power laser is long and is made to spread the inside of the optical fiber of low loss, it becomes important. As for the spectrum output of diode pump neodymium laser, it is common to consist of some modes in which it has the line breadth of the kilohertz unit in which spacing of several GHz opened. As shown by AOKI etc., when the power per mode exceeds a certain threshold, on these conditions, SBR poses a problem. Therefore, since power is distributed to each mode, the maximum-permissible power in the inside of a fiber is determined by the number of the oscillation modes of pump LD. Since it is attained by using the large laser material of a gain peak, although big frequency spacing is required for the laser which fills such demands, it can work some longitudinal modes. Of course, the laser oscillation spectrum of laser may be narrower than the width of face of a gain peak. The effectiveness in the laser to which it is easy to carry out multiplex longitudinal-mode operation (for example, spatial hole burning) of the laser must be carefully optimized, if the line breadth at the time of actuation is made to make it max.

[0008] The optimal condition of the spectrum of laser is determined by at least three factors in application of fiber OPUTIKUSU in a GIGAHERUTSU field. From a mode beat noise, it is required that mode spacing should be large as much as possible. Since conditions required in

order to control SBR suggest use of laser material with wide gain peak width, the longitudinal mode which was able to open some large spacing can be worked. Demand that a fiber transmission bandwidth is large leads the conditions of making D(lambda) **lambda into min to the last. This condition is satisfied only when laser is worked on the wavelength from which D (lambda) serves as zero when the value of **lambda is large. Thus, the polarization laser which has a short laser cavity which is the longitudinal mode which was able to open some large spacing, and works on the zero distribution point of a fiber is needed.

[0009] Diode pump neodymium laser is a useful source of high power for fiber optic SUBIDEO transmission. Especially one useful source of a laser beam is a laser diode pump-neodymium dope yttrium RICHIUMUFUTSU ghost (Nd:YLF, i.e., NYLF). 1047nm and strong 1-micrometer transition by 1053nm are widely used for a Q switch, mode locking, and application like the formation (intracavity doubling) of a twice as many internal cavity as this. Although 1321nm and weak 1.3-micrometer transition by 1313nm are also interesting, especially 1313nm line is zero-dispersion wavelength lambdao in a silicon-dioxide fiber. It is interesting in respect of application of fiber OPUTIKUSU at the reason for being very near.

[0010] A birefringence laser crystal like Nd:YLF is characterized by optical ellipsoid, and it has typically the strong gain and the strong absorption spectrum of a polarization dependency. In Nd:YLF, strongest 1-micrometer (4 F3/2 -> 4F11) transition is 1047nm [sigma(pi) =18x10-20 cm2] and 1053nm [sigma(sigma) =12x10-20 cm2]. 1.3-micrometer (4 F3/2 ->4 I13/2) transition equivalent to these is 1313nm [sigma(sigma) =3x10-20 cm2] and 1321nm [sigma(pi) =3x10-20 cm2]. Furthermore, 800nm absorption spectrum polarizes strongly. In Nd:YLF, an absorption spectrum consists of the two main peaks, 792nm and 797nm, 1%, 792nm is alpha(sigma) =1cm-1 and alpha(pi) =9cm-1, and 797nm of these absorption coefficients is alpha(sigma) =3cm-1 and alpha(pi) =6cm-1. The pump of Nd:YLF will be simply carried out by about 800nm laser diode synchrotron orbital radiation by this.

[0011] The host crystal of yttrium aluminum perofskite (YAlO3, i.e., YAP, or YALO) is used for other laser. The polarization dependence gain of YALO is reported. Alternative loss of polarization all over a cavity (For example) Polarization like BURYU star prism, and a wavelength selector Appl.Phys.Lett. by [MASEI (G. A.Massey) by which the laser oscillation property by the pumping in alignment with the crystal main shaft accompanying the increment by using is investigated, the 18th volume, No.1 (1971), Jour.Quantum by MASEI Electron., QE-8 volume, No.7 (1972), 669 - 674 pages, and Optics by abb RAMOBITCHI (A. Abramovici) Comm, the 61st volume, No.6 (1987), 401 -404-page]. The polarization and wavelength selection nature of a laser cavity which used YALO about various fluorescence spectra are reported to Appl.Phys.Letts by a weber (M. J.Weber) etc., the 15th volume, No.10 (1969), and 342 - 345 pages. It is suggested to Appl.Phys. by the weber, the 42nd volume, No.42 (1972), and 4996 - 5005 pages that the anisotropy of the stimulated-emission cross section of the main shaft about various transition of the Nd dope YAP can suit specific laser application in Nd:YAP. Appl.Phys.Letts. by a bus (M. Bass) etc., the 17th volume, No.9 (1970), and especially 395-398 pages inquire about Q switch actuation in which Nd dope YALO laser was improved, and the gain factor of Nd in YALO being dependent on the crystal orientation nature of a laser rod main shaft and selection of the crystallographic axis of the optimal gain characteristics are further reported to them. However, the same research result about YLF is not obtained yet.

[0012] As for Nd:YLF laser, it is common that the include angle theta between an optical axis (namely, crystal c-axis) and an axis of circulation is worked at 90 degrees, a pumping is performed for propagation by 792nm pi polarization absorption peak along with an a-axis, and

laser oscillation is performed by 1047nm transition of pi polarization. If a 1-micrometer cavernous reflector is used, 1047nm radiation of pi polarization of the power between 50-100mW will be obtained. Typically, the linearity polarization of this output is carried out by 1000:1 or more polarization ratios. Positive single line operation (1047nm or 1053nm) is attained by arranging a BURYU star plate on pi of a crystal, or sigma shaft. Equivalent power is obtained also in which wavelength. However, output polarization is very sensitive to the array of the shaft of a BURYU star plate, and a crystallographic axis. As shown by the Jones matrix analysis, ** to which a little arrays come makes a polarization output an oblong. Furthermore, it not only increases the magnitude (die length) of the whole source of laser, but a BURYU star plate decreases effective power.

[0013] 1053nm laser oscillation whose sigma polarization Nd:YLF did has two problems, although it is realizable at theta= 0 degree (namely, propagation in alignment with a c-axis). The first problem is that laser already polarizes and there is (that is, operation by both polarization is possible) first. [no] For a mechanical reason, the birefringence of few include angles from which it divides laser into two groups (it is easy to carry out laser oscillation of both) of two or more orthogonal modes since it is not guaranteed any longer that propagation meets a c-axis correctly arises. When laser spreads along with a c-axis, to an optical axis, rather than laser power with an include angle of 90 degrees (theta= 90 degrees), typically, I hear that the 2nd problem has low output power, and it has it no less than 20%. At theta= 0 degree, only comparatively weak sigma polarization spectrum depends this on the inefficient nature of the pumping that a pump is possible. Moreover, control of laser light polarization is also difficult in this case. Although one of the polarization can be stopped by adding a BURYU star plate to a cavity, step must be correctly kept with a crystallographic axis with difficult discovery, otherwise, it becomes a RIOTTO filter (see the supra by umbra MOBITCHI (Ambramovici) about Nd:YAP). Generally, it is easy to add a BURYU star plate to the rod of the easy a-axis of discovery.

[0014] Similarly, the Nd:YLF laser system which polarized can work by 1313 and 1321nm. Generally, the output of 25-50mW is obtained with the input control power of 200mW. If Nd:YLF laser is worked on the conditions of BURYU star plate nothing and theta= 90 degrees, laser will work to coincidence by both 1313nm line of sigma polarization, and 1321nm line of pi polarization. These two lines have the same gain substantially, and it tends to carry out both laser oscillation.

[0015] Operation by the two above-mentioned lines is seen by many laser material in 1.3 micrometers. For example, it is Nd:GGG which works by 1323 and 1331nm in Nd:YAG which works by 1319 and 1338nm, and a list. In many **, only when the RIOTTO filter or an additional wavelength selection element like an etalon is added to the laser cavity, single line operation is made. In Nd:YLF, polarization control with a BURYU star plate is used in order to realize single line operation on one of wavelength. Although 1313nm operation is made by the propagation in alignment with a c-axis (namely, theta= 90 degrees), it has the same pumping as the 1053nm laser in alignment with a c-axis, and the problem of polarization.

EFFECT OF THE INVENTION

[Effect of the Invention] The laser system which can carry out the pump of the optical fiber so that the distributed loss by output wavelength may serve as min can be offered without using an additional structure.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] U.S. Pat. No. 3,624,545 (No. 1971 November 30 issue) by the loss (Ross) is described about the optical pump solid state laser which consists of the YAG rod by which a flank pump is carried out by at least one semi-conductor diode laser. Similarly, in order that U.S. Pat. No. 3,753,145 (August 14, 1973 issue) by Choi Sulla (Chesler) may carry out the edge pump of the neodymium dope YAG rod, it is said that one or more luminescence semiconductor diodes are used. Using the array of a pulse diode laser, in order to carry out the edge pump of solid-state-laser material like the neodymium dope YAG is stated to U.S. Pat. No. 3,982,201 (No. 1976 September 21 issue) by Rosencrantz (Rosenkranttz) etc. Appl.Phys.Lett. according to Sipes (D. L.Sipes) to the last, the 47th volume, and No. -- in order to carry out the edge pump of the neodymium dope YAG, by using the semi-conductor diode laser array which focused strongly reported 2, 1985, and 74 - 75 pages of things for which the pumping radiation which has the wavelength of 810nm is changed into the output radiation which has the wavelength of 1064nm at high effectiveness.
[0017] Although a certain kind of the polarization dependence gain and the absorption spectrum of a birefringence laser crystal are recognized in the above-mentioned reference, as for such a crystal, it is common to be worked at theta= 0 degree or theta= 90 degrees. A more important thing is zero-dispersion wavelength lambda 0. It is not combined with the directivity of a laser crystal [how it can use for fitting that the effectiveness acquired by working an optical fiber optimizes the shaft of propagation, and directivity optimizes the performance in laser operation mode, decreasing an optical noise, or an optical spectrum].
[0018] One of the purposes of this invention is offering the new laser system which carries out the pump of the optical fiber so that laser's may make distributed loss min.
[0019] It is compact and other purposes of this invention are things which used without the additional optical element for the optical fiber Nd:YLF which supplies polarization and for which laser system with sufficient energy efficiency is offered.
[0020] The further purpose of this invention is offering laser system equipped with birefringence laser material and the holder which arranges this laser material so that the pumping in zero-dispersion wavelength may be made.
[0021] The further purpose of this invention is offering the diode pump Nd:YLF laser of an easy configuration of consisting of the fewest possible structures which carries out the pump of the optical fiber by about 1.3 micrometers.
[0022] this invention -- being the further -- others -- the purpose is offering the means to which the output spectrum of laser system is fitted.

MEANS

[Means for Solving the Problem] In order to attain the above purpose, the laser system of this invention The holder which has the edge which receives the pumping light from a source, and the opposite edge which transmits a laser beam to an optical fiber, and has the predetermined axis of circulation of a direction which connects between these edges, It is arranged at the above-mentioned holder so that it may be attached between the edges of the above-mentioned holder at the above-mentioned holder, it may have at least one optical axis and the include angle between at least one optical axis of a parenthesis and the above-mentioned axis of circulation may consist of 0 degree for 90 degrees. When the light from the source of the above is received, it has the laser material which has an optical spectrum including the main polarization dependence spectrum peak in wavelength almost equal to the zero-dispersion wavelength of the above-mentioned optical fiber.

[0024] Since birefringence solid-state-laser material like Nd:YALO or Nd:YLF has the gain factor of transition of a strong polarization dependence absorption spectrum and dope material typically, control in the operation mode of laser equipped with such a gain medium is made by control of the direction of the crystallographic axis of the laser material in polarization or a laser cavity. In birefringence solid-state-laser material, a gain factor is dependent on the include angle theta and crystall luminescence shaft over the optical path which passes along a crystal. Furthermore, it is expressed by the refractive index of that this relation is normal and the crystal to abnormality polarization, and the trigonometric function of an include angle theta although the parameter relation showing a gain factor which is different on the various transition lines of the dope material under crystal exists [Born (M. Born) and Principles of Optics by WORUFU (E. Wolf), the 6th edition, Chapter 14, Pergamon Press, New York 1980]. So, a gain factor is optimized by choosing theta.

[0025] One important application of this invention is fitting output wavelength to the zero-dispersion wavelength of the optical fiber combined with the output of laser. According to this invention, an output polarizes without [without it uses a BURYUTA plate, and] changing the energy of other wavelength, the output wavelength of laser is united with the zero-dispersion wavelength of an optical fiber, and a frequency beat also decreases. Furthermore, since a conventional polarization control means like a BURYU star plate is unnecessary, the die length and magnitude of the whole laser can be decreased.

[0026] Many of other advantages and descriptions of this invention are described in the following examples.

EXAMPLE

[Example] Although this invention can be carried out with many gestalten, two examples are describing below. It does not pass over these to what shows an example of this invention, and this invention is not restricted to these.

[0028] Each structure of the elementary solid-state laser system 10 is illustrated by drawing 4 . Especially, in this example, it has the source 12 of a pump, a lens 14, the laser material 16, the output coupler 18, and the holder 20 as a source, a lens, laser material, and an output coupler. A

holder 20 has edge 20b transmitted to an optical fiber 22 in light from laser material along with an axis of circulation D.

[0029] An optical pumping means, i.e., the optical radiation from a source 12, focuses to edge 16a of the laser material 16 with the focus means 14, i.e., a lens, in more detail. Preferably, the laser material 16 is solid ** and is ** in which a pump can be carried out by the optical-pumping radiation from the source of a laser diode. The light emitted by the laser oscillation of the laser material 16 is contained all over the linearity stationary wave optical cavity defined by reflective covering of the front face of reflecting surface 18a of the output coupler 18, i.e., a mirror, and opposite edge 16a of laser material. The laser material 16 is manufactured by cutting so that I may hear that the optical path which passes along a crystal has a certain relation to a crystall luminescence shaft and it may be defined, so that it may be explained in detail later.

[0030] The holder has composition which supports the main structures of laser system 10 about the holder 20, i.e., a maintenance means. As illustrated especially, the holder 20 has two or more crevices for attaching other structures of laser system 10, and Slot 12s, 14s, 16s, and 18s, i.e., scooping outs. If the above-mentioned structure is attached in these slots, these structures will be automatically arranged in the direction of an optical axis D, i.e., the shaft of propagation. These structures are fixed to a holder 20 by using the conventional mechanical means or the conventional conventional adhesion means (namely, bond material) like screw attachment. The more detailed contents about a holder are described at United States patent 4th transferred to the applicant of this invention, and No. 31,795. This contractor will admit that it is not necessary to equip a holder 20 with a lens 14, and that the output coupler 18 is attached in end 16b of the laser material 16 from the following explanation.

[0031] Preferably, although the laser material 16 contains the solid-state chosen from the group which an active substance and an active substance become from the vitrification and the crystallization base material which are having the matter which is the stoichiometric component of laser material doped, it is not restricted to this. More preferably, although an active substance contains the ion of chromium, titanium, and a rare earth metal, it is not restricted to this. It is describing in more detail about the conventional solid-state-laser material CRC Handbook of Laser Scienceand Technology, the 1st volume, the Weber (M. J.Weber) work, CRC company issue, 1982, 72 - 135 pages and Laser Crystals by Kaminsky, the 14th volume of the SHUPU ringer series of optics, a SHUPU ringer company, and 1982. The conventional base material to neodymium ion contains a glass yttrium aluminum garnet (Y3 A15O12, i.e., YAG), YAlO3 (it is described as YALO or YAP), the neodymium dope LiYF4 (it is described as YLF), Gd3 Ga 5O12 (it is described as GGG), and Gd3 Sc2 Ga 3O12 (it is described as GSGG). When used as an example as laser material of the solid-state laser system with which the pump of the neodymium dope YAG is carried out optically, by absorbing the light which has the wavelength of about 808nm, the pump of this laser material can be carried out, and it can emit the light which has the wavelength which is about 1064nm or about 1320nm.

[0032] A source 12 is equipped with the heat sink and/or 12h of thermoelectric-cooling equipment relevant to laser diode 12d and this by the example shown in drawing. Using a flash lamp, light emitting diode (here, high brightness diode and a high brightness diode array being included), and a laser diode (here, a laser diode array being included) for the pump of solid-state-laser material, i.e., excitation, is known well. Conventional light emitting diode and a conventional laser diode carry out output radiation which has the wavelength of the range of about 630 to about 1600nm as a function of a constituent. Such equipment that carries out pump radiation of wavelength effective for carrying out the pump of the laser material 16 is used for

practical use of this invention. For example, the wavelength of the equipment based on GaAlAs is changed to about 750 to about 900nm by changing the constituent of equipment. The source based on GaAlP emits the wavelength of the range from about 1000nm to about 1600nm by the same approach. A suitable power source is used at the time of operation of an optical-pumping means. The electric code from the source 12 of laser to a power source is not shown all over drawing.

[0033] That of a lens 14 is that ****** makes the light from a source 12 focus to the laser material 16. All the conventional means for a focus can be used. For example, the combination of a refractive-index change lens (GRIN), a ball lens, an aspheric lens, or an optical element etc. is used. If laser diode 12d is used as a source 12 of a pumping, the edge on the front face of an output of a laser diode, i.e., a source, will be put on field 16a on the front face 16 of an input, i.e., laser material, and the relation (butt-coupled relationship) of base association, without using a lens 14. Base association means association near enough to which only 1 mode volume carries out the pump of the laser material 16 with a transmission interruption area small enough here, in order that the emission beam of the pumping radiation emitted from the source of a laser diode may essentially support only one transmission-mode laser operation (namely, TEM00) in laser material.

[0034] The light emitted by the laser material 16 is turned to an optical fiber 22 by the output coupler 18. The optical coupler 18 is like the mirror which penetrates some of light (they are not all) emitted from the laser material 16. For example, internal-surface 18a may be equipped with covering used for this coupler from the former which has about 95% of reflection factor. Covering of the same class as this is applied to opposite edge 16b of the laser material 16. In such a case, the main function can transpose the output coupler 18 to the optical means which is making parallel light given to an optical fiber 22.

[0035] An optical fiber 22 is the conventional thing. As an example of the optical fiber of the communication link type of Corning, Inc. [Corning glass (Corning Glass Works), the Corning communication link section, New York, 14831, and the U.S.] which can be got in a commercial scene, it is SMF-28 at the zero-dispersion wavelength of 1314nm and 1312nm, respectively. CPC3 Single-mode optical fiber and SMF-21 CPC3 There is single-mode optical fiber.

[0036] Since the laser material 16 is cut from Boolean (boule: rough, for example, Nd:YLF) one of a crystal unlike the conventional thing, the crystallographic axis (c-axis) has the acute angle theta to Propagation D (refer to drawing 1). The laser material 16 is carrying out the exact cylinder, i.e., a rod configuration, here. However, all the configurations known from the former are used. The laser material 16 is equipped with the Nd:YLF rod whose concentration of Nd is about 1 atom % by a certain example. Edge 16a is covered so that 85% or more may be made to penetrate in the wavelength (for example, 792nm) of the light from a source 12, and so that it may have a high reflection factor (HR) in output wavelength (for example, 1313nm) almost equal to the zero-dispersion wavelength of an optical fiber 22. Opposed face 16b is covered so that it may have 0.25% or less of reflection factor in output wavelength. As a certain example, the laser material 16 is 5mm in the diameter of 3mm, and die length.

[0037] About the theta= 45-degree axis of circulation D, the 1313nm gain in an ordinary ray becomes larger than the gain of one of the lines in an extraordinary ray to a c-axis, and polarization single line laser oscillation is possible. This is realized also at an include angle like the throat between about 30 to 60 degrees (at such an include angle, the gain of an extraordinary ray decreases 25% from peak value). Making it work near theta= 60 degree by the reason for emphasizing the strong pi polarization component of an absorption spectrum has many

advantages. "Walk-off" (namely, birefringence) is equipped with additional polarization and a wavelength selection device. Normal and extraordinary-ray mode separate from input edge 16a of the YLF crystal 16 spatially mutually. For this reason, one of the modes can be efficiently laid on top of a pump spot. If the greatest superposition is carried out about a normal mode, the wavelength selection effectiveness will tend to be reinforced by this.

[0038] All over the cavity as shown in example drawing 4 , the theta= 45-degree laser using the 4mm length Nd:YLF laser rod whose Nd concentration is about 1% was made. The curved-surface reflector 18 with which radius of curvature reflects 1.32 micrometers 99.5% by 70mm was used in order to form a cavity with a die length of 26mm. The laser power exceeding 25mW was simply obtained by 792 or the 797nm pumping. The linearity polarization of the output beam was carried out by 1000:1 or more polarization ratios. It turned out that the spectrum of an output beam is measured by the 0.35m monochromator, consequently it consists of some longitudinal modes centering on 1313nm. Vibration was not detected in any of other wavelength between 1310 and 1400nm. Although the transmission-mode profile of a laser output was in agreement with the GAUSHAN profile, this shows that single transmission-mode operation was attained. This was confirmed by the noise measurement which uses a spectrum analyzer. The peak divided into the noise spectrum only 5.34GHz which is the description of the mode beat of TEM00 transmission mode was seen. This spacing is determined by cavernous length and this contractor will recognize that it can be made to increase by using a shorter cavity. Furthermore, we used the technique same about Nd:YAG, in order to carry out operation to which the shot noise was restricted by 10MHz to 20GHz.

[0039] Other examples are shown in drawing 6 . Here, laser material consists of two Nd:YLF crystals 16A and 16B which approached mutually. Crystal 16B is cut so that the c optical axis may become about 90 degrees to an axis of circulation. Crystal 16A is cut so that the c-axis may become about 0 degree to an axis of circulation. As for surface 16b close to the front face and the output coupler 18 between these two crystals, it is desirable to be covered so that it may have non-reflexibility (AR) to the wavelength (for example, 792nm of a laser diode) of 1313nm and the source of the above. An output beam will be equipped with about 1313nm sigma polarization if the above arrangement is carried out.

[0040] Although the concept of changing the direction of the crystallographic axis of laser material to an axis of circulation has said that an optical fiber is supplied, larger application is possible for this concept. Since mode competition and mode fluctuation may be minimized in the desired mode, the polarization dependence gain and the absorption spectrum of a birefringence solid-state-laser crystal radical can be used in order to optimize the mode (for example, CW, a Q switch) of laser operation.

[0041] Since a noise is a function near [where laser works] the wavelength, this concept can be used also in order to reduce an optical noise. Furthermore, this concept is applicable to both monopodial and an optically biaxial birefringence laser crystal. Finally, the concept of this invention is applicable to a place, for example, a single wavelength output, i.e., single line operation, where it is required from a laser crystal, specific wavelength, i.e., dominant wavelength, anywhere. It can **, if it avoids attaching other equipments (for example, BURYU star plate etc.) in order that making it equal substantially may have practical availability in the zero-dispersion wavelength of the optical fiber especially related in this wavelength and it may fit an output spectrum to it further.

[0042] Probably, by the above description, various modification will be possible to this contractor. The above description is only for explaining drawing and is aimed at teaching this

contractor the method of performing this invention. Much modification is possible to this invention. For example, a holder may be hollowed and can also have the cross section (refer to drawing 5) of a semicircle, a circle, or a rectangle (U.S. Pat. No. 4,731,795 drawing 2). Furthermore, reflecting surface 18a is good also as covering of a up to [edge 16b of the laser material 16]. Moreover, the description of this invention is demonstrated also for much modification and substitution of laser material. For example, 1053nm laser of polarization is realizable using Nd:YLF worked at theta= 30 degrees. Although, as for a normal beam of light, all serve as 1053nm peak of normal polarization, as for an extraordinary ray, 1047nm peak becomes [1053nm peak] 25% 75%. Since 1047nm peak is 1.5 times as large as 1053nm peak, two peaks in an extraordinary-ray spectrum have both smaller than a normal 1053nm peak. Thus, 1053nm operation of polarization has a result. The strongest pump band happens to the abnormality polarization by 797nm. Thus, many design changes are made based on the pneuma of this invention shown in the claim. of course, such modification -- a claim -- it comes out inside.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the top view of the Boolean end side of Nd:YLF showing the directivity of the crystallographic axis of the optical element which forms the laser material of this invention.
[Drawing 2] It is the side elevation of the optical element of drawing 1 .
[Drawing 3] It is drawing showing the end face of the optical element of drawing 2 seen from the arrow-head 3 direction of drawing 2 .
[Drawing 4] It is the schematic diagram of one example of the laser system containing the optical element from drawing 1 to drawing 3 .
[Drawing 5] It is the fragmentary sectional view of the holder of drawing 4 seen from the direction of an arrow head 5.
[Drawing 6] It is the fragmentary sectional view showing the example which used two laser crystals for the holder of drawing 4 .
[Description of Notations]
12 Source of Pumping
14 Lens
16 Laser Material
18 Output Coupler
20 Holder
22 Optical Fiber
